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A DEEP BOUNDARY CURRENT AT THE FOOT OF THE NEW SOUTH
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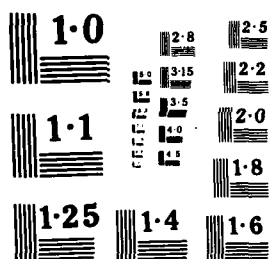
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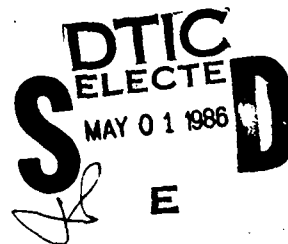
RANRL TECHNICAL MEMORANDUM
(EXTERNAL) 16/85

A DEEP BOUNDARY CURRENT AT THE FOOT OF THE
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P.J. Mulhearn, J.H. Filloux*, F.E.M. Lilley†,
N.L. Bindoff† and I.J. Ferguson†

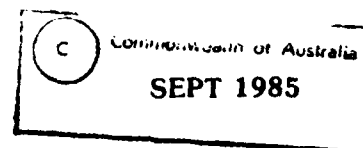
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A DEEP BOUNDARY CURRENT AT THE FOOT OF THE
NEW SOUTH WALES CONTINENTAL SLOPE?

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ABSTRACT

Preliminary evidence is presented for the existence of a deep, northwards boundary current flowing, at least intermittently, at the foot of the continental slope off New South Wales. Measured velocities were approximately 10 cm/s^{-1} . Some eddying motion or meandering was apparent.

- * Scripps Institution of Oceanography, La Jolla, California
† Research School of Earth Sciences, Australian National University

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POSTAL ADDRESS: The Superintendent, Maritime Systems Division, WSRL
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1. Introduction

Deep western boundary currents, carrying polar waters equatorwards have been identified in many ocean basins (Warren, 1981). These basins range in size from small ones in the Indian Ocean, such as the Madagascar and West Australian Basins, to large ones such as the South Pacific with its western boundary, effectively, at New Zealand and the Tonga-Kermadec Ridge. The observed currents have widths between 100 and 1000 km, heights between 800 and 3000 m, and transports of 2×10^6 to $24 \times 10^6 \text{ m}^3 \text{ s}^{-1}$. Currents in the North Atlantic's deep western boundary current are of order 10 cm s^{-1} .

The Tasman Basin between Australia and New Zealand is closed off to the north at depths greater than 2850 m and so constitutes a separate basin. Little evidence for a deep western boundary current in the Tasman has been published. Warren (1973) in a trans-Pacific hydrology section at 43°S found a region of slightly reduced temperature at the foot of the continental slope of the East Tasman Plateau, but other water properties were relatively featureless there. Jenkins (1984), using sediment seismic stratigraphy, found some indications of a deep boundary current along the Australian continental margin from 33°S to 40°S such as gentle moating at the foot of the slope and strong erosion of the outer Bass Canyon Fan (40°S). Near 33°S the boundary current appears to be joined by another bottom current from the south-east and evidence for an equatorwards current at the foot of the continental slope is very clear north of 33°S . The geological age of the bottom bed forms found on these seismic profiles is not clear and more direct evidence is required to be sure of present day currents. Mulhearn (1983) estimated transports in the Tasman's deep boundary current

using the Stommel and Arons (1960) model. At 36°S this was $0.4 \times 10^6 \text{ m}^3 \text{ s}^{-1}$, considerably smaller than that found in observed, deep boundary currents.

Evidence from current-meter and Nansen cast data are presented in this paper for the existence of a deep, northwards flowing boundary current which may be intermittent off the New South Wales coast. The data were obtained as part of a larger study, to be presented elsewhere, into the relation between near-surface and abyssal flows in the East Australian Current System.

From December 1983 to March 1984 a number of instruments were deployed on the Tasman Abyssal Plain, and Nansen casts were obtained on the deployment and recovery cruises. While the instruments were in place a meander of the East Australian Current intruded southwards and pinched off to form a warm-core ring. The data to be presented here are mainly from the period before the meander moved southwards over the moorings, because from then on the bottom flows became strongly influenced by the East Australian Current System.

2. Instrumentation

The near bottom observations consist of velocities and temperatures from an RCM-5 Aanderaa current meter, temperatures from a sensor attached to a nearby pressure gauge, and temperatures and bottom velocities in the magnetic east-west direction from a vertical electric field measuring instrument (VEF) placed further to the east. Positions of instruments are shown in figure 1 and further data on them are in Table 1.

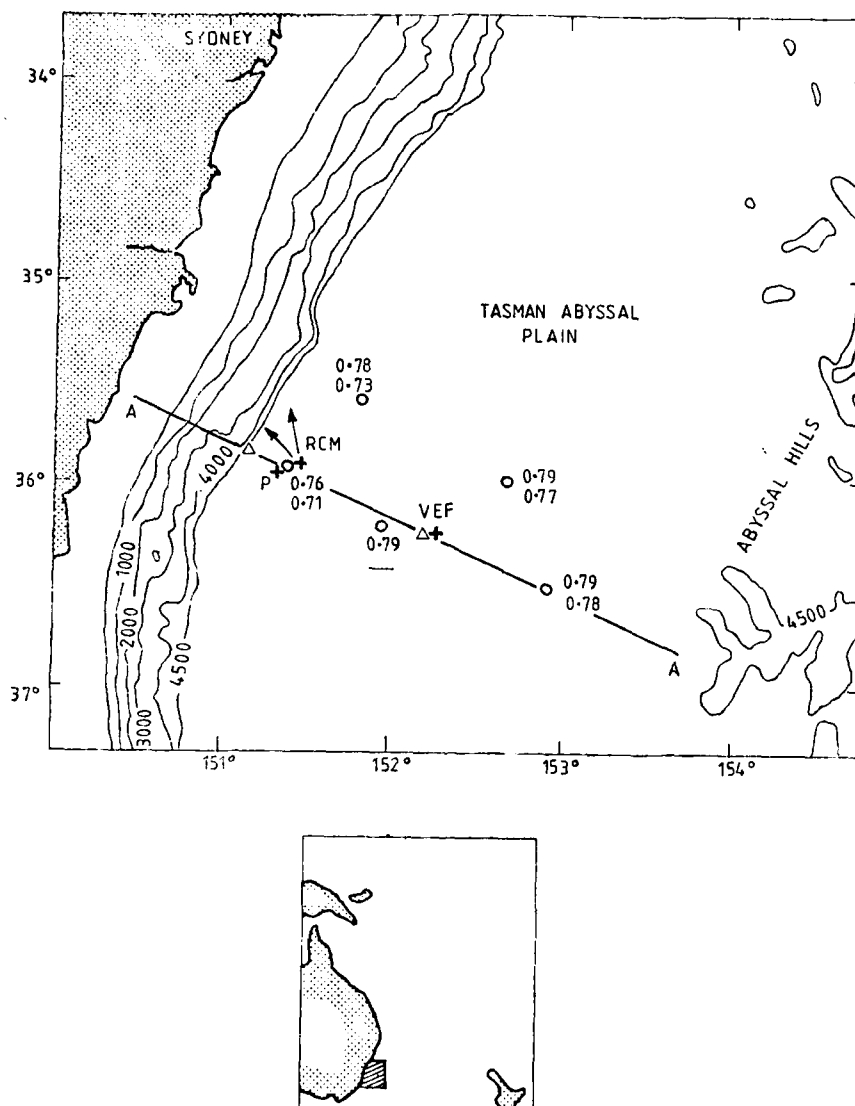


Fig.1 Map showing positions of current-meter, RCM, pressure gauge, P, vertical electric field instrument, VEF, and Nansen casts: o, those on deployment cruise (10-14 Dec 83); Δ those on recovery cruise (27 Mar and 3 Apr 84). Upper numbers next to o's are potential temperatures at 4500 m and lower ones are potential temperatures at 4700 m. Arrows indicate current directions (see text.)

Every 15 minutes the Aanderra RCM-5 current meter recorded instantaneous values of temperature and direction and a 15 minute average of speed. The starting speed of the RCM-5, according to its specifications, was 2 cm/sec and for zero turns of its rotor in a sampling period a speed of 1.5 cm/sec was recorded. There were periods when the 15 min. average speed was below 2 cm/sec but, because higher speed periods are of interests here, this will not affect our conclusions. The electronic circuit with the RCM-5's thermistor had not been modified for work at abyssal depths and so only had a resolution of 0.024°C per least count and an accuracy of $\pm 0.05^\circ\text{C}$. The RCM-5 was moored 100 m above the bottom, attached to an acoustic release, with glass floats for buoyancy.

From the vertical electric field, E_z , the velocity, V_x , in the magnetic east-west direction, averaged between 2 and 160 m above the bottom, was obtained via the relation

$$E_z = -V_x B_y ,$$

where B_y is the horizontal component of the earth's magnetic field. Full details of this instrument and data obtained are in Bindoff et al (1985). It is only referred to briefly here as specifying conditions well away from the continental slope.

The temperature on the vertical electric field instrument's pressure case was measured with a silicone resistor sensor bridge to a resolution of $0.25 \times 10^{-3}^\circ\text{C}$ per least count. Absolute values of temperature are not known, only the variability above a base level. An identical temperature sensor was on the wall of the pressure gauge near the RCM and was approximately 0.75 m above the bottom.

Measurements of temperature, salinity and sample depth were obtained using Nansen bottles equipped with deep-sea reversing thermometers. Casts were performed in two stages - a shallow cast to approximately 1,100 m and a deep one usually to within 120 m of the sea-floor. During a cast the ship, HMAS COOK, was manoeuvred using bow thruster and active rudder so as to keep the hydrology-winch wire vertical. During a station the distance of the deepest Nansen bottle above the sea-floor was estimated from sonic depth and length of wire out. From subsequent analysis this distance varied between 92 m and 15 m, except for one cast on the deployment cruise at 36°11'S, 151°56'E (290 m), and the two mentioned from the recovery cruise (483 m and 237 m).

The reversing protected thermometers on the lowest five bottles were made by Gohla and had a range of -2°C to +6°C with divisions marked every 0.02°. The unprotected ones were Watanabe Keiki with a range of -2°C to +60°C. All other reversing thermometers were Watanabe Keiki, the unprotected ones having a range of -2°C to +30°C or +35°C and the protected having a range of -2°C to +30°C. Nansen bottles were also made by Watanabe Keiki. Conservatively estimated accuracies for temperatures were $\pm 0.01^\circ\text{C}$ below 3000 m and $\pm .05^\circ$ above. Salinities were measured with an Autolab inductively coupled salinometer model 601 Mk III, to an accuracy of approximately 0.003×10^{-3} .

Measurement and data analysis procedures were standard. From the data, values for potential density relative to 3,000 dbars and potential temperature were calculated.

Navigation was via fixes obtained from the Transic Navigation Satellite System with a Single Channel Magnovox MX1102, with dead-reckoning between fixes. Positions would have been accurate within 0.5 km or less.

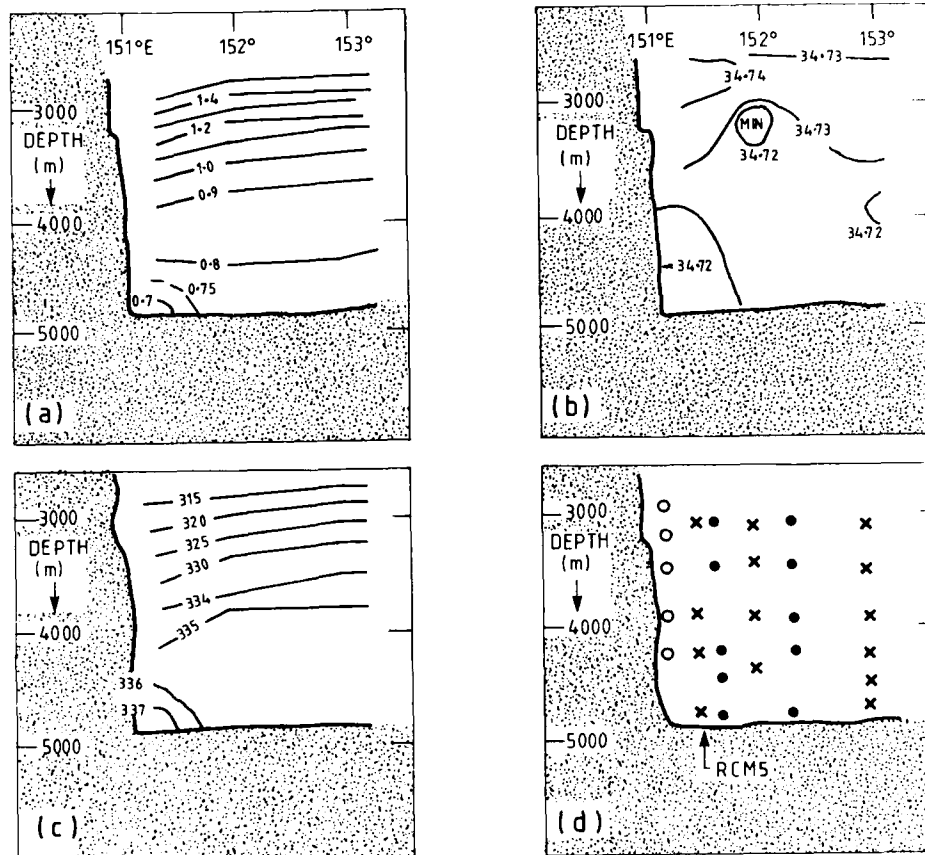


Fig.2 Sections along A-A on deployment cruise (10-13 Dec 83)

(a) potential temperature ($^{\circ}\text{C}$); (b) salinity ($\times 10^{-3}$);

(c) Potential density, ρ , relative to 300 dbars. Numbers are

($\rho - 1,130.00$) $\times 10^2$ (kg/m^3); (d) Positions of samples on Nansen

casts: x, deployment cruise stations or A-A; •, deployment cruise

stations north of A-A. o recovery cruise station close to coast.

3. Results

The sections obtained along the line AA in figure 1 on the mooring deployment cruise, are shown in figure 2. A region of denser water with reduced potential temperature, and slightly reduced salinity can be seen at the foot of the continental slope. In figure 1 potential temperatures at depths of 4,500 m and 4,700 m are presented. Both stations near the coast have lower temperatures than those farther east.

The first six days of the current meter record are presented in figure 3. Velocity fluctuations due to tides and inertial oscillations are apparent. On longer time scales, over the first three days the speed dropped by approximately 2.5 cm s^{-1} and the direction swung from approximately 345° to 315° . These directions are indicated on figure 1. Near 1200Z on 15 December the temperature rose sharply by 0.05°C and the current swung back to the north and, just before 1200Z on 16 December the speed dropped rapidly, and the direction became erratic. The temperature stayed relatively high and constant till 20 January when the bottom flow came under the influence of the East Australian Current.

The temperature sensor on the current meter was 100 m above the bottom. Another temperature sensor attached to a pressure gauge approximately 0.75 m above the bottom, was located approximately 2km to the south-west. The latter's record is shown in figure 3. Unfortunately it did not commence recording till 15 December when the current-meter's temperature rose sharply. It can be seen that the two records are quite dissimilar. The pressure gauge's temperature did not become relatively high and constant till 24 December, nine days after the current-meter's.

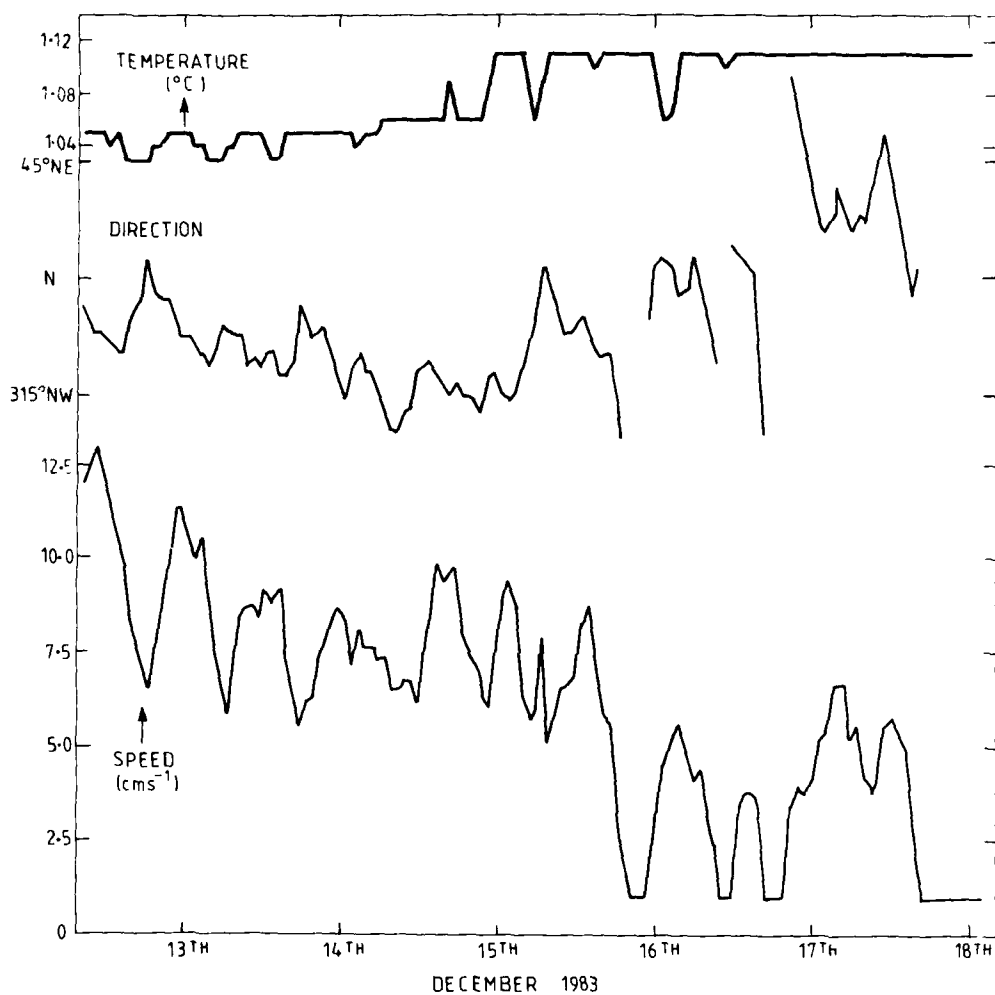
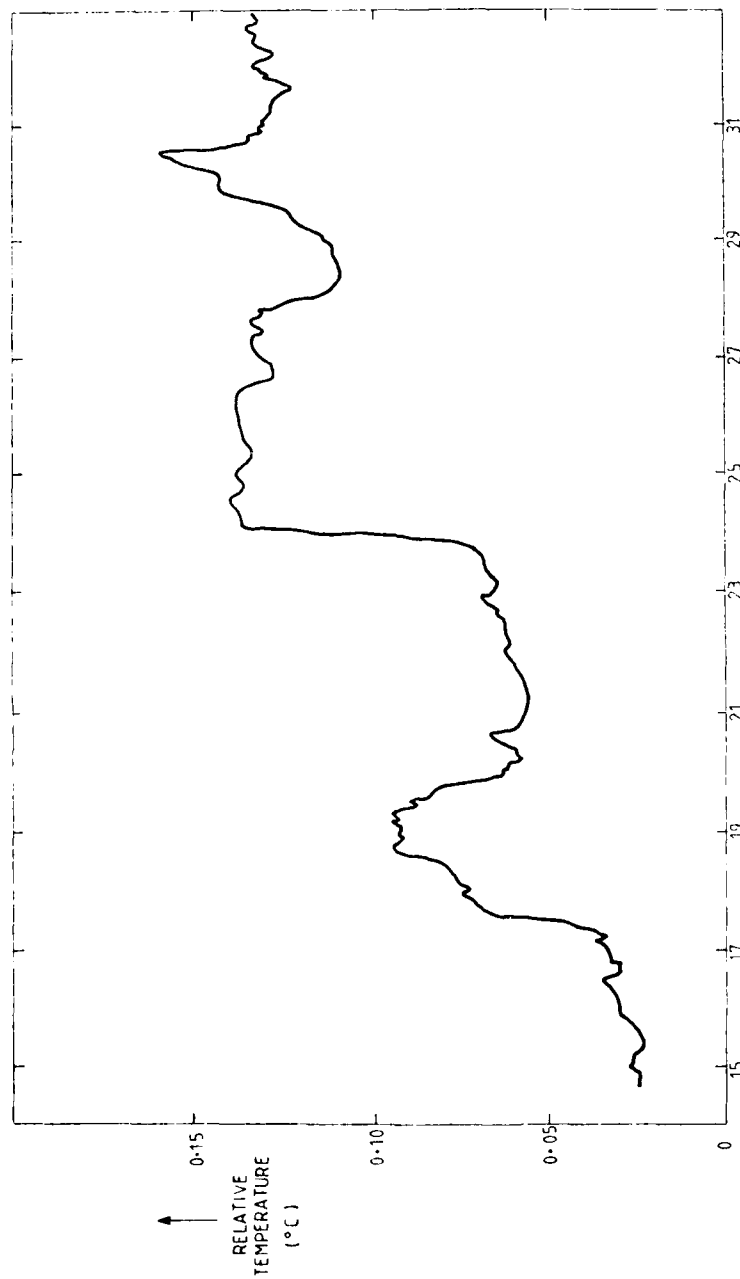


Fig.3 Current meter time series of speed, direction and temperature.
 Dates are indicated at 1200Z.



DECEMBER 1983

Fig.4 Temperature record from pressure gauge. Dates are marked at 1200Z. Zero on vertical axis is an unknown base level.

After mid January the two records became highly correlated. At the vertical electric field instrument, the magnitude of the daily average magnetic east-west velocity was of order 1 cm s^{-1} and the temperature was relatively high and constant within $\pm 0.025^\circ\text{C}$ till early January. In mid-January the temperature dropped 0.11°C and velocity fluctuations increased in magnitude. (See Bindoff et al, 1985).

There were no further occurrences of a cold, northwards flow, rapid enough to prevent stalling of the current-meter rotor, up to 20 March 1984, the date of the meter's recovery. A Nansen cast close to the foot of the continental slope did reveal a region of cold bottom water a week later. See figure 1 for positions. Nansen cast data from the two cruises are shown in figure 5. Although the cast just referred to did not reach the sea floor, it showed reduced temperatures below 3900 m.

4. Discussion

There are theoretical (e.g. Stommel and Arons, 1960) and experimental (e.g. Warren, 1981) reasons for expecting a deep boundary current against the western edge of the Tasman Sea. The observations presented here suggest that there is a narrow current with eddies or meanders on its seaward side. The direction and relatively short duration of the flow at the current meter site suggest an eddy or a meander passed by. The dissimilarity between the temperature records from the pressure gauge and the current meter suggest that these instruments were near the edge of this cold water mass. The low temperatures found right at the foot of the continental slope on the recovery cruise, when no reduced temperatures were seen on the moorings, support the idea of narrow current. However this current would be much narrower than those observed elsewhere, but this may be compatible with the small theoretical transport mentioned in the Introduction.

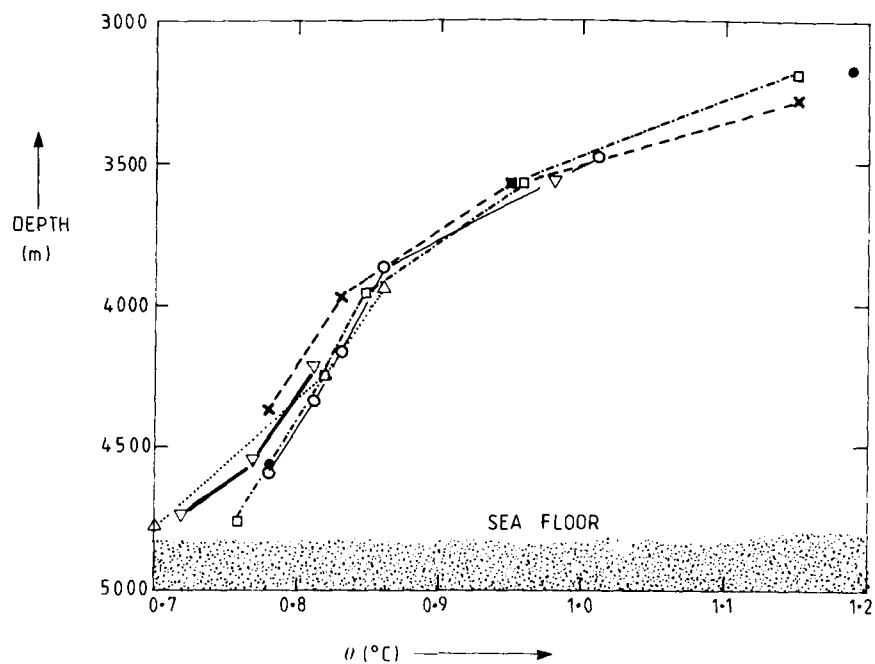


Fig. 5 Deep potential temperature profiles. Deployment cruise stations :
 A, nearest coast on A-A; O, near VEF on A-A; 7, nearest coast
 north of A-A; □, north-east of VEF.
 Recovery cruise stations : x, nearest coast; o, near VEF.

The measurements are reminiscent of the laboratory flows reported in Griffiths and Linden (1981), in which large eddies or meanders are seen to grow on a narrow coastal current. The density driven currents in these flows has a width of order $\sqrt{g'h/f}$ and speed of order $\sqrt{g'h}$, where $g' = g\Delta\rho/\rho$, is reduced gravity, h is current depth, f is Coriolis parameter, $\Delta\rho$ is density difference between current and ambient water and ρ is average density. Taking $h = 1000$ m from the Nansen cast nearest the coast, and $\frac{\Delta\rho}{\rho} = 1.76 \times 10^{-5}$ from the in-situ density section, gives $\sqrt{g'h}/f = 3.5$ km and $\sqrt{g'h} = 0.41$ m/s. The experimental results suggest that the current-meter, which was approximately 30 km out from the foot of the continental slope, was at the edge of an abyssal eddy or meander as it swept by. This suggests the latter had a diameter approximately ten times the current's width, which is similar to that found in laboratory models. The measured velocities, of approximately 8 cm s^{-1} , are also of the right order. Given a 30 km diameter, the eddy's or meander's Rossby Number is 0.02 and it is rotationally dominated.

Acknowledgements

The help of the officers and crew of HMAS COOK with the performance of Nansen casts and the deployment of the current meter is acknowledged. The crew of RV SPRIGHTLY are thanked for help in the meter's recovery and Mr F. Boland of CSIRO's Division of Oceanography is thanked for transcribing data from the meter's tape to a computer compatible one. Discussions with Dr R. Griffiths of ANU have been very helpful.

TABLE 1

Instrument	Variables	Lat.(S)	Long(E)	Water Depth (m)	Instrument height above bottom(m)
Aanderaa RCM-5	σ_t , T	35°54.4'	151°23'	4850	100
Sensor on press. gauge (P)	T	35°55'	151°22'	4850	0.75
VEF	V_x (magnetic), T	36°14'	152°15'	4736	77 (2-160). Approx. 1m for T

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4. Title A DEEP BOUNDARY CURRENT AT THE FOOT OF THE NEW SOUTH WALES CONTINENTAL SLOPE?		5. Security a. document UNCLAS b. title c. abstract UNCLAS UNCLAS	6. No Pages 19 7. No Refs 7
8. Author(s) P.J. MULHEARN, J.H. FILLOUX (SCRIPPS), F.E.M. LILLEY (ANU), N.L. BINDOFF (ANU) AND I.J. FERGUSON (ANU)		9. Downgrading Instructions N/A	
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16. Abstract PRELIMINARY EVIDENCE IS PRESENTED FOR THE EXISTENCE OF A DEEP, NORTHWARDS BOUNDARY CURRENT FLOWING, AT LEAST INTERMITTENTLY, AT THE FOOT OF THE CONTINENTAL SLOPE OF NEW SOUTH WALES. MEASURED VELOCITIES WERE APPROXIMATELY 10 CM S ⁻¹ . SOME EDDYING MOTION OR MEANDERING WAS APPARENT.			

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